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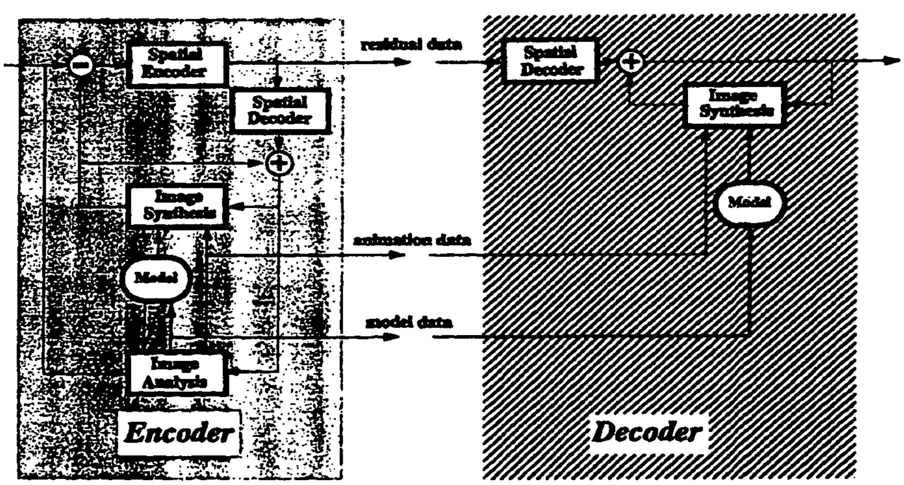

Transmitter **Receiver**

A unified video compression structure.

(57) Abstract

This invention is in the area of real-time mobile video communication. The core of this invention is that the computation consuming image analysis part is moved from the transmitter to the receiver. With the invention, highly efficient video compression algorithms, e.g. MPEG4, H.263 can be used by mobile terminals with very low complexity. This makes real-time mobile video transmission a reality with very low power terminals.

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Real-Time Mobile Video Communication with Low Power Terminals

1 Background of the invention

1.1 Field of the Invention

Mobile communication is currently one of the most emerging markets and is expected to continue to expand. Today the functionalities of mobile communications are very limited. Only speech or data can be handled. It is expected that image information, especially real-time video information, will greatly add to the value of mobile communication. Low cost mobile video transmission is highly required by many practical applications, e.g. *mobile visual communication, live TV news report, mobile surveillance, telemedicine, virtual reality, computer game, personal travel assistance, underwater visual communication, space communication, etc*. However, there are indeed some problems with inclusion of live video information into mobile communications. Different from speech information, video information normally needs greater bandwidth and processing performance. In contrast, the mobile terminals of today and tomorrow suffer from certain limitations, e.g.

1 *mobile terminals usually have limited power, typical transmission output power levels, 10 microwatts - 1 watt.*

2 *the terminals have limited capability to wirelessly transmit data, 1kb/s -10kb/s*

Based on these facts, real-time mobile video transmission can only be achieved when a high efficient compression algorithm with very low implementation complexity can be implemented.

1.2 Description of the Prior Art

To compress motion pictures, a simple solution is to compress pictures on a frame by frame basis, e.g by means of the JPEG algorithm. This will result in a rather high bitrate although at low complexity. To achieve high compression efficiency, we need to employ advanced video compression algorithms. Up to now, different types of video compression algorithms have been developed. Typical examples include **H.263-type block-based, 3D model-based,** and **segmentation based coding algorithms**. Although based on different coding principles, these algorithms adopt a similar coding structure, namely the closed-loop coding structure. This unified coding structure is shown in Fig.1. In this structure, important blocks are **image analysis, image synthesis, spatial encoder/decoder** and **modeling**. Video compression algorithms differ themselves in the image analysis and synthesis part. Amongst the blocks, the most computation consuming one is image analysis. The following are typical image analysis tasks performed in different algorithms:

H.263 coding algorithm *The main function of the image analysis part in H.263 algorithm is to perform motion estimation. For motion estimation, commonly a block matching scheme is used. Unfortunately, motion estimation is very time- and power-consuming although the employed motion model is very simple. For example, if a simple correlation measure is used, the sum of the absolute value of differences(SAD) is computed. For a full search over a +- 7 displacement range at QCIF(176x144 pixels) resolution and 10 frames/s, the SAD computation would have to be performances over 57 million times each second. With increased search range and a finer resolution of motion vectors is needed, the computation will be greatly increased.*

Model-based coding algorithm *The task of image analysis here is to extract*

animation parameters based on models. The models can be given a prior or to be built during coding processing. Since the animation parameters are related to 3 dimensional information, e.g. 3D motion and shape and the observable is 2D image information, a good strategy is needed. A powerful tool based on the analysis by synthesis principle (ABS) is shown in Fig.2. Obviously, this is the second closed-loop appearing in the encoder. The purpose of using this loop is to aid or verify image analysis. This is done by means of the image synthesis block by comparing with the reference image. Therefore, the complexity of image analysis is rather complicated. In contrast, image synthesis is much simpler. In addition, in the beginning of the session, the analysis part needs to do "initial works", such as, object location or identification, feature points localization, the fitting of a generic model to the specific object appearing in the scenes, and initial pose estimation. This type of work gives rise to a very heavy computational load.

Segmentation-based coding algorithm *The task of image analysis here is to segment images into objects according to assumed definition of objects, to track the objects and to estimate their motion or shape parameters. The commonly used models are 2D planar object with affine motion, flexible 3D objects with 3D motion. Obviously, the estimation of the motion and shape parameters associated with these models needs sophisticated operations. In addition, another heavy task carried out by the image analysis is to maintain, update and choose the models.*

In summary, two important observations about the image analysis part in the advanced video compression algorithms are that

(1) *Due to the involvement of image analysis, the complexity of the encoder is much higher than that of the decoder.*

(2) *computational loads caused by image analysis in the beginning is usually heavier than that during the coding process. This requires that the encoder has a strong peak computational ability.*

(3) *The decoder must operate exactly as the encoder does. That is, the decoder is passively controlled by the encoder*

These points make advanced video algorithms difficult to implement in low power terminals to achieve live video communication.

2 Summary of the invention

To achieve video communication, very low power terminals should employ video compression algorithms with the following features:

(1) *low complexity of the encoder and decoder*

(2) *high compression efficiency*

(3) *the operation of the encoder should be remotely controlled.*

To satisfy these requirements, it is not necessary to reinvent the wheel. This invention will make it possible to use current or future video compression algorithms to achieve video communication with low power terminals. The key idea of this invention is to move the

communication with low power terminals. The key idea of this invention is to move the image analysis part to the receiver or an intermediate point in the network. This is illustrated in Fig.3. In this invention, we distinguish two different concepts: *transmitter/receiver* and *encoder/decoder*, which are mixed together in conventional video communication systems. In this invention, the encoder does not necessarily sit in the transmitter. Instead, a main part of the encoder remains in the transmitter while the computation consuming part, image analysis is put in the receiver. In this way, image analysis is performed in the receiver instead of the transmitter. The generated animation and model data are then sent back to the transmitter to run normal encoding processing. Therefore, the encoder is still a virtually complete system but physically is distributed across both the transmitter and receiver. Obviously, implicit conditions to enable such communication is that the receiver has enough power to perform complex image analysis and the latency between the receiver and transmitter should be low. In fact, the second condition, low latency is not necessary in our invention if model-based or object-oriented coding schemes are used. The kye is the first condition, which is easily satisfied in the applications mentioned in section 1. For example, a high performance computer or server can be used to communicate with these low power terminals. In principle, this invention enables a supercomputer performance at a very low cost.

Furthermore, this invention is also supported by communication possibility. According to the Shannon information theory, the channel capacity is determined by

$$C = Blog(1 + \frac{S}{N}) \tag{1}$$

The increase in the signal power will increase the channel capacity. Since at the receiver side, sufficient power is available, it is no problem to transmit model and animation data to the transmitter.

In the case that the transmitter has certain computational ability and the latency is low, a second configuration scheme can be employed, which is illustrated in Fig.4. In this scheme two analysis blocks are employed. These two analysis blocks are either {\sf hierarchical}, e.g. the image analysis part in the receiver performs rough estimation of animation and model data while the one in the transmitter refines the obtained results from the receiver, or {\sf separate}, e.g. the analysis in the transmitter is in charge of tracking while the one in the receiver is in charge of initial estimation.

3 Description of the preferred embodiments

In our invention, the receiver will take part in the coding processing. The image analysis is performed in the receiver. In comparison with the original scheme, a significantly different part is that the input to the image analysis block is no longer the current frame but the previous frame. Therefore, a key issue for image analysis is its ability to predict the parameters which are normally from the current frame. Assume that previously decoded frames, I^*_{t-1} and I^*_{t-2} are available at the receiver side and the frame I^*_{t-1} is also available at the transmitter side. Now the task is to transmit the current frame I^*_{t}.

Image analysis is performed by using the previously decoded frames I^*_{t-1} and I^*_{t-2} based on the model V^*_{t-1} in the receiving side:

$$[\tilde{A}_t, \tilde{M}_t]^T = analysis(I^*_{t-1}, I^*_{t-2}, V_{t-1}) \tag{2}$$

where $\tilde{A}_t$ are the animation data and $\tilde{M}_t$ are the model data which will be used to update the employed model. The obtained animation data and model data are compressed and then transmitted back to the transmitter.

At both the transmitter and receiver the employed model is updated by the model data

$$\tilde{V}_t = model\_update(V_{t-1}, \tilde{M}_t) \tag{3}$$

Here we distinguish two cases:

case I: no refinement

$$A_t = \tilde{A}_t$$
$$M_t = \tilde{M}_t$$
$$V_t = \tilde{V}_t \tag{4}$$

case II: refinement

A new image analysis taking the current frame as input is performed to refine the results estimated from previously decoded frames

$$[A_t, M_t]^T = analysis\_refine(I_t, I^*_{t-1}, \tilde{A}_t, \tilde{M}_t, \tilde{V}_t) \tag{5}$$

and the employed model is also refined

$$V_t = model\_refine(\tilde{V}_t, M_t) \tag{6}$$

At the transmitter, the prediction of the current frame can be rendered by an image synthesis operation based on the updated model V_t,

$$I'_t = render(A_t, V_t, I^*_{t-1}) \tag{7}$$

The texture residual signal is

$$\delta I_t = I_t - I'_t \tag{8}$$

The residual information will be compressed by applying spatial coding methods, e.g. DCT on the residual signal.

$$R_t = DCT(\delta I_t) \tag{9}$$

Note that in case II the animation and model residual signals δA_t and δM_t are also needed to be compressed and transmitted to the receiver. These two residual signals are defined as

$$\delta A_t = A_t - \bar{A}_t \qquad (10)$$

and

$$\delta M_t = M_t - \bar{M}_t \qquad (11)$$

4 Specified techniques

4. 1Motion prediction technique for two-way mobile communication

In two-way mobile communication, one of the main problems is that the available channel capacity is very limited, e.g. 9.6kb/s for GSM standard. To transmit video through the mobile channel, advanced video coding algorithms must be employed. H.263, a video coding algorithm standardized by ITU[1] is very suitable for this purpose. This standard coding algorithm can also be described by the scheme shown in Fig.1. Since H.263 is a block-based video compression algorithm, from table 1, we will see that *image analysis* corresponds to *block-based motion estimation}*, *image synthesis* to *block based motion compensation*. There is no information about modelling.

The main problem with this kind of configuration is that the limited power available in the mobile terminals prohibits complicated signal processing operations, e.g. motion estimation. In addition, both the transmitter and receiver have low power. Fortunately, there is no direct communication necessary for these two low power terminals. The two-way communication is carried out through basestations where sufficient power is available.

A practical solution is to move the motion estimation part from the transmitter to the base station. That is, the encoder virtually sits across the transmitting terminal and the base station. Now the task of image analysis is to estimate animation data in the base station. Since block-based algorithm is employed, the animation data contains motion information only.

Assume that previously decoded frames, I^*_{t-1}, I^*_{t-2}, are available at the base station and the frame I^*_{t-1} is also available at the transmitter and the receiver. To make a prediction of the current frame, motion vectors for the current frame must be provided. This is done in the base station where motion prediction has to be made

$$\bar{A}_t = analysis(I^*_{t-1}, I^*_{t-2}) \qquad (12)$$

The obtained motion information $\bar{A}_t$ is then transmitted to both the transmitter and the receiver.

With the obtained motion vectors $\bar{A}_t$, the motion vectors to be used can be obtained by either $A_t = \bar{A}_t$ or $A_t = analysis\_refine(I_t, I^*_{t-1}, \bar{A}_t)$ depending on which schemes are used. Thus, a motion compensated prediction of the current frame is given by

$$I'_t = render(A_t, I^*_{t-1}) \qquad (13)$$

Obviously, the key to this technique lies in the performance of motion prediction (12).

Now, we present a new technique to perform motion prediction. The core part in this invention is the employment of a new search strategy which allows us to make use of existing search methods, e.g. *block-matching algorithm* to achieve motion prediction.

Assume that a block-matching scheme is employ. To predict the current frame I_t using the previous I^*_{t-1}, the current frame must be segmented into rectangular blocks first and then one displacement vector (u^*,v^*) is to be estimated per block through

$$\min_{u,v} \sum_{(n_1,n_2)\in R} |I_t(n_1,n_2) - I^*_{t-1}(n_1-u, n_2-v)|^2 \qquad (14)$$

where R is a rectangular block centered on (n_1,n_2)

Since I_t is not available in the base station, the motion vector $(u^*,v^*$ can not be recovered at time t from the constraint (14). To achieve motion prediction, the interframe motion is assumed to follow a physical motion model. Under this assumption, we have

$$I_t(n_1,n_2) \approx I^*_{t-1}(n_1-u^*, n_2-v^*) \approx I^*_{t-2}(n_1-au^*, n_2-bv^*) \qquad (15)$$

where a and b are constants which are specified by the assumed motion model. When a uniform motion is assumed, $a=2$ and $b=2$.

Now the constraint (14) can be rewritten as

$$\min_{u,v} \sum_{(n_1,n_2)\in R} |I^*_{t-2}(n_1-au, n_2-bv) - I^*_{t-1}(n_1-u, n_2-v)|^2 \qquad (16)$$

The motion vector u^*,v^* can be estimated from the new constraint.

The motion vectors u^*,v^* are the animation data $\tilde{A}_t$ specified in equation (12). If no refinement is performed, then $u=u^*$ and $v=v^*$. Now the motion compensated prediction of the current frame can be given

$$I'_t(n_1,n_2) = render(A_t, I^*_{t-1}(n_1,n_2)) = I^*_{t-1}(n_1-u, n_2-v) \qquad (17)$$

If a refinement operation is performed, a similar result can be obtained.

4.2 3D Motion Prediction Technique for Object-Oriented Video Coding Applications

In object-oriented video coding schemes, an important image analysis task is to estimate the 3D motion of the objects appearing in the scene. For example, in videophone and video conference scenes, a typical object is the human head. The task there is to extract two types of information: face definition parameters and face animation parameters. They correspond to model data and animation data defined in this invention. Advanced computer vision techniques are usually used to extract these data. As is known, these algorithms are computationally intensive, which usually can not be afforded by low power terminals. Our invention can handle this problem by moving the image analysis part to the receiver. The

core of this technique is to employ Kalman filtering to predict 3D motion of objects appearing in current frame.

Assume the 3D motion of objects can be modeled as a dynamic process

$$A_{t+1} = f(A_t) + \xi \qquad (18)$$

where the function f models the dynamic evolution of the state vector A_t at time t. The measurement process is

$$Y_t = h(A_t) + \eta \qquad (19)$$

where the sensor observations Y are a function h of the state vectors and time. Both ξ and η are white noise processes having known spectral density matrices.

In the specific applications, the state vector A_t consists of the motion parameters to be estimated and the observation vector Y_t contains the available measurements, like pixel-based, feature-based measurements. The function f may be a discrete-time Newtonian physical model of 3D motion.

Using Kalman filtering, we can obtain the optimal linear estimate $\tilde{A}_t$ of the state vector A_t

$$\hat{A}_t = A_t^* + K_t(Y_t - h(A_t)) \qquad (20)$$

where A^*_t is the prediction of the state vector A_t.

The prediction of the state vector A_{t+1} at the next time step is

$$A_{t+1}^* = f(\hat{A}_t) \qquad (21)$$

if the measurement Y_t at time t is available.

Since the image analysis part is moved to the receiver, what is available there is the measurement Y^{t-1}. Therefore, we can only obtain the optimal linear estimate $\tilde{A}_{t-1}$ of the state vector A_{t-1}

$$\hat{A}_{t-1} = A_{t-1}^* + K_{t-1}(Y_{t-1} - h(A_{t-1})) \qquad (22)$$

With it the prediction of motion parameters of the current frame is obtained

$$A_t^* = f(\hat{A}_{t-1}) \qquad (23)$$

The predicted motion parameters A^*_t are sent to the transmitter. The transmitter synthesizes a prediction image I'_t of the current frame, then the residual signal between the prediction and current frame is compressed and transmitted to the receiver. The receiver reconstructs the current frame with the received residual signal. Then the current measurement Y_t can be extracted. With Y_t, the prediction of the next frame can be derived by using (20)(21).

More specifically, this technique can be used for three cases:

Case I: the terminal has weak computational ability and the connection from the receiver to the terminal is of low delay}

The predicted motion parameters are used in the terminal and only texture residual signal is transmitted to the receiver.

Case II: the terminal has certain computational ability and the connection from the receiver to the terminal is of low delay

The predicted motion parameters will be refined by using the current frame. The refined motion parameters are used to predict the current frame. The texture residual signal is transmitted to the receiver. Additional residual signals between the refined motion parameters and predicted ones are also transmitted to the receiver.

Case III: the connection from the receiver to the terminal is of long (or irregular) delay}

No information is sent from the transmitter to the receiver for a while. The predicted motion parameters are used to drive animation at the receiver.

The enclosed drawings show:

Fig. 1: A unified video compression structure.
Fig. 2: Image analysis based on the analysis by synthesis principle (ABS)
Fig. 3: New implementation scheme where image analysis is performed at the receiver
Fig. 4: Alternative implementation where image analysis is performed at both the transmitter and the receiver.}

CLAIMS

1) Method for the transferring of moving pictures where a predicted picture frame is obtained through motion compensation techniques and then compared with the actual picture frame, a deviation signal is generated corresponding to the difference between the actual and the predicted frames and motion information is for compensation sent to the receiving station, **characterized in** the motion estimation being carried out outside the picture sending unit and in that the predicted motion information generated by motion estimation is not only sent to the receiving unit but also to the sending unit in which the predicted picture frame is compared with the real picture frame and the resulting deviation signal is sent to the motion compensating prediction unit and the receiving station or terminal.

2) Method according to claim 1, **characterized in** that the motion prediction is carried out outside the sending unit, e.g. a base station in the mobile phone case or a central station in a wired phone case and that communication between the motion estimator and the sending unit and the receiving unit respectively is via ordinary wire or cellular telephone networks, or other media.

3) Method according to claim 1 and 2, **characterized in** duplex communication with the motion estimation for both ends being arranged centrally or apart from the picture sending and receiving terminals.

4) Method according to any of the preceding claims, **characterized in** a regular and additional or initial updating of the entire picture or parts thereof.

5) Method according to any of the preceding claims, **characterized in** that the information flow from the picture sending unit is smaller than or equal to that from the central base station to the picture sending unit.

6) Communication network for the transfer of moving pictures in accordance with claim 1, **characterized in** that equipment for motion estimation is arranged in one or several base stations.

7) Method for the transferring of moving pictures where a predicted picture frame is obtained through image analysis and then compared with the actual picture frame, a deviation signal is generated corresponding to the difference between the actual and the predicted frames and information is for compensation sent to the receiving station, **characterized in** the image analysis being carried out outside the picture sending unit and in that the predicted information generated by image analysis is not only sent to the receiving unit but also to the sending unit in which the predicted picture frame is compared with the real picture frame and the resulting deviation signal is sent to the compensating prediction unit and the receiving station or terminal.

8) Method according to claim 7, **characterized in** that the motion prediction is carried out outside the sending unit, e.g. a base station in the mobile phone case or a central station in a wired phone case and that communication between the motion estimator and the sending unit and the receiving unit respectively is via ordinary wire or cellular telephone networks, or other media.

9) Method according to claim 7 or 8, **characterized in** duplex communication with the image analysis for both ends being arranged centrally or apart from the picture sending and receiving terminals.

10) Method according to any of the preceding claims 7 to 9, **characterized in** a regular and additional or initial updating of the entire picture or parts thereof.

11) Method according to any of the preceding claims 7 to 10, **characterized in** that the information flow from the picture sending unit is smaller than or equal to that from the central base station to the picture sending unit.

12) Communication network for the transfer of moving pictures in accordance with claim 7, **characterized in** that equipment for image analysis is arranged in one or several base stations.

13) Method for the transferring of moving pictures where a predicted picture frame is obtained through image analysis and then compared with the actual picture frame, a deviation signal is generated corresponding to the difference between the actual and the predicted frames and information is for compensation sent to the receiving station, **characterized in** the image analysis being carried out outside the picture sending unit and in that the predicted information generated by image analysis is sent to the sending unit in which the predicted picture frame is compared with the real picture frame and the resulting deviation signal is sent to the compensating prediction unit.

14) Method according to claim 13, **characterized in** the sending of the deviation signal also to a receiving station or terminal together with the predicted picture frame information.

15) Method according to claim 14, **characterized in** that the image prediction is carried out outside the sending unit, e.g. a base station in the mobile phone case or a central station in a wired phone case and that communication between the prediction estimator and the sending unit and the receiving unit respectively is via ordinary wire or cellular telephone networks, or other media.

16) Method according to claim 13 or 14, **characterized in** duplex communication with the image analysis for both ends being arranged centrally or apart from the picture sending and receiving terminals.

17) Method according to any of the preceding claims 13 to 16, **characterized in** a regular and additional or initial updating of the entire picture or parts thereof.

18) Method according to any of the preceding claims 13 to 17, **characterized in** that the information flow from the picture sending unit is smaller than or equal to that from the central base station to the picture sending unit.

19. Method for video communication, **characterized in** the image analysis being carried out in the receiver or an intermediate point in a network.

20. Method according to any of the previous claims **characterized in** the image analysis

being motion prediction.

21) Communication network for the transfer of moving pictures in accordance with any of the previous claims 13 to 20, **characterized in** that equipment for image analysis is arranged in one or several base stations.

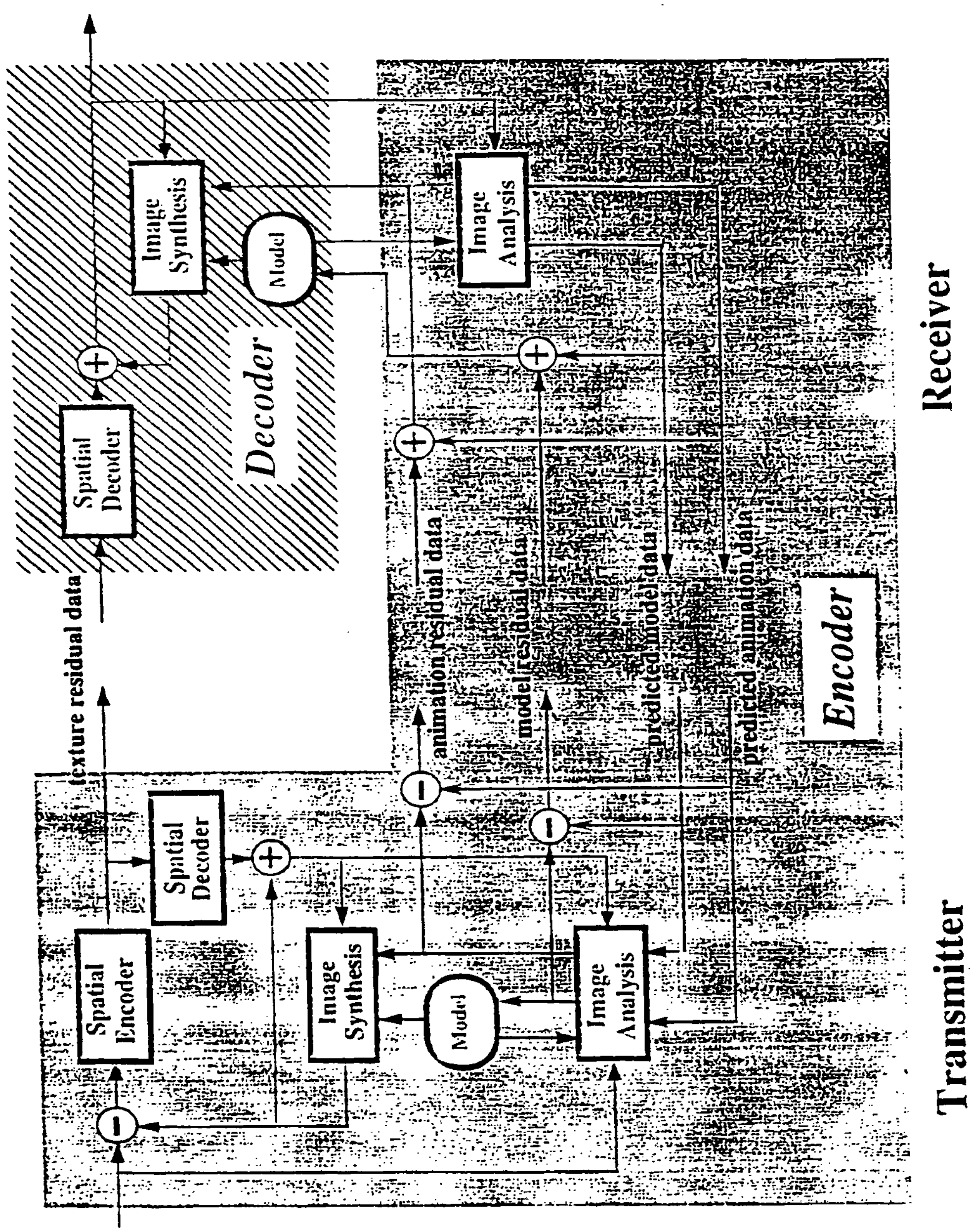
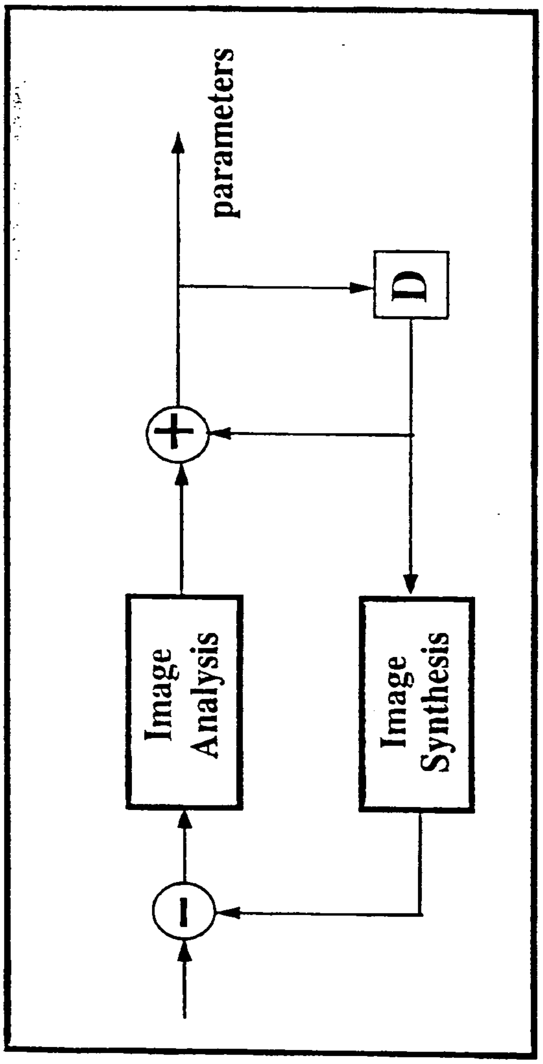


Figure 4: Alternative implementation where image analysis is performed at both the transmitter and the receiver



ABS

Figure 2: Image analysis based on the analysis by synthesis principle(ABS).

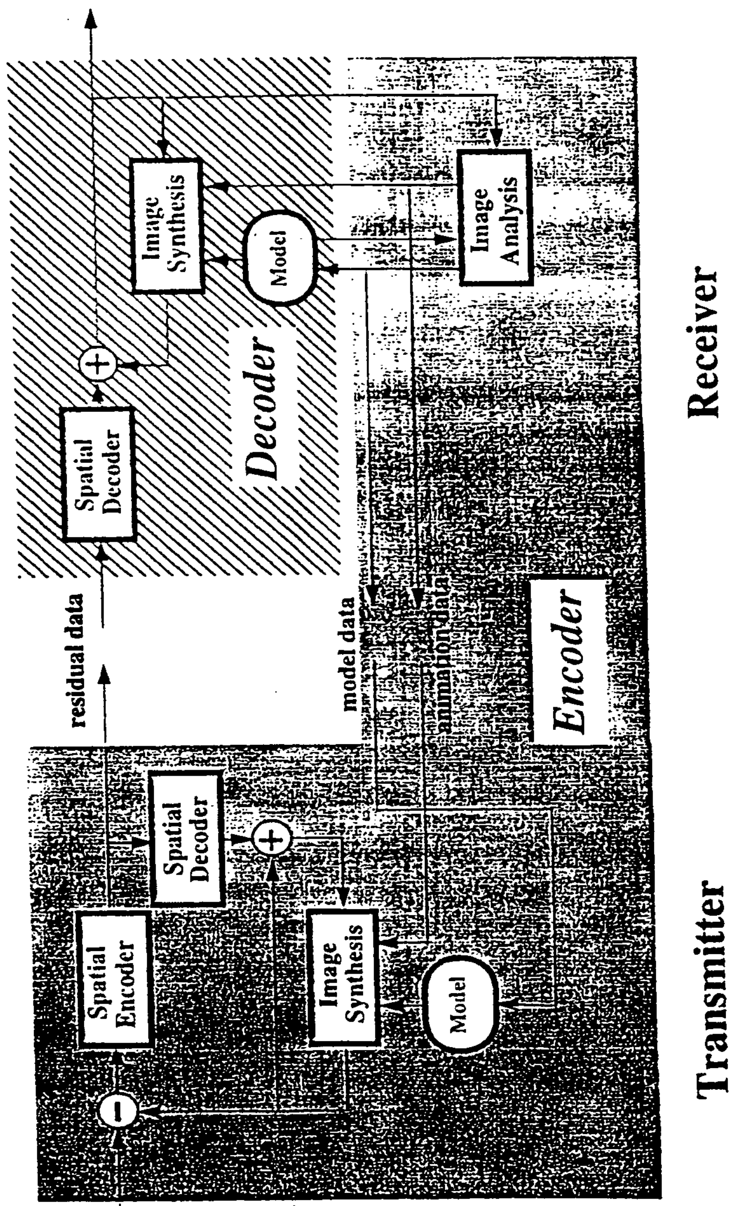


Figure 3: New implementation scheme where image analysis is performed at the receiver.

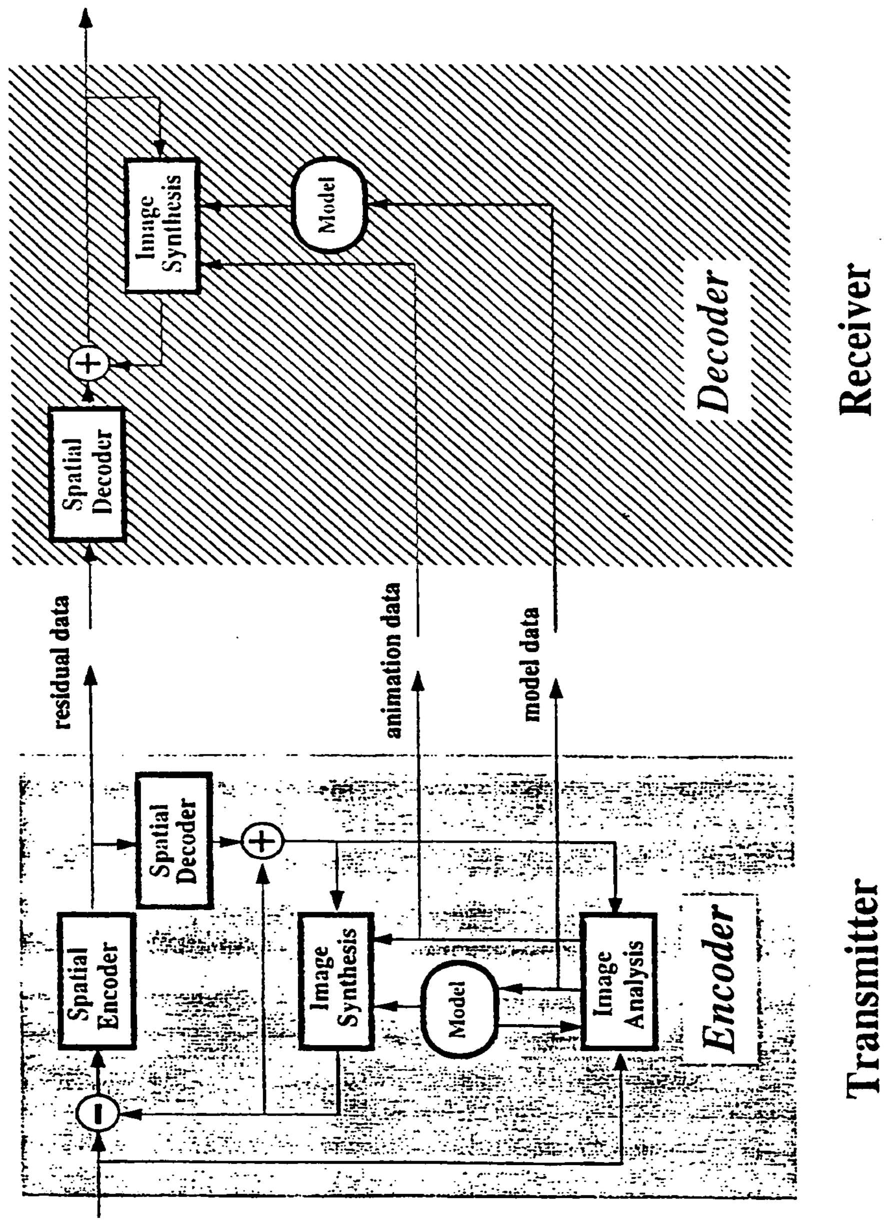


Figure 1: A unified video compression structure.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00030

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04Q 7/32, H04Q 7/22, H04Q 7/30, H04N 7/173, H04N 7/50 // H04N 5/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04Q, H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5550756 A (SHINICHIRO OHMI ET AL), 27 August 1996 (27.08.96), abstract --	1-21
A	US 4703350 A (BRIAN L. HINMAN), 27 October 1987 (27.10.87), abstract --	1-21
A	GB 2222338 A (THE PLESSEY COMPANY PLC), 28 February 1990 (28.02.90), abstract -- --------	1-21

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 May 1998	04 -06- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Michel Gascoin Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT
Information on patent family members

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International application No.
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